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Inside IAQ

EPA's Indoor Air Quality Research Update

Indoor Air Quality Problems and Engineering Solutions Symposium and Exhibition
July 21-23, 2003
Research Triangle Park, NC
(See Page 1 for Details)

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INDOOR AIR QUALITY SYMPOSIUM

Indoor Air Quality Problems and Engineering Solutions, an international symposium cosponsored by the U.S. EPA's Office of Research and Development and the A&WMA (Air and Waste Management Association), will be held July 21-23, 2003, in Research Triangle Park, NC, at the Sheraton Imperial Hotel and Convention Center.

H.E. Barney Burroughs, renowned expert in the field of indoor environmental quality, will deliver the keynote address. This year's symposium will include sessions on such timely and relevant topics as: Safe Buildings for Homeland Security, Mold and Biocontaminants, Indoor Pollutant Sources, Models and Databases, Particulate Matter, Air Cleaning, IAQ Problems from Polluted Soil and Water, Special Topics, and Product Certification.

The technical program will include 60 presentations, with parallel sessions on one day, July 22. Poster sessions and an exhibition of related products and services are planned. A reception is also planned for the first evening. The conference site has convenient access to RDU airport, nearby restaurants, shopping, and entertainment.

Two excellent, professional development courses will be offered on July 20, 2003: How to Assess & Improve Indoor Air Quality by Rishi Kumar and Mold in the Indoor Environment by Richard Shaughnessy and Kenneth Martinez.

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Immediately following the symposium, a tour of the U.S. EPA's beautiful, new, state-of-the-art, "green" research facilities, shown in the accompanying photo, will be offered.

We are looking forward to an interesting, exciting symposium, and we hope you can join us. For further information on the program and registration, visit A&WMA's web site at www.awma.org/events or contact Denise Stotler at (412) 232-3444, ext. 3111, stotler@awma.org. Registration discounts are available for A&WMA members, students, and government employees. For information on the exhibition, contact Gene Garbowsky, A&WMA, (412) 232-3444, ext. 3102, ggarbowsky@awma.org. For further information on the technical program, contact Jim Jetter at (919) 541-4830, jetter.jim@epa.gov.

ESTIMATION OF OVERALL MASS TRANSFER COEFFICIENT FOR VOC EMISSIONS FROM AQUEOUS SOLUTIONS

The ability to estimate volatile organic compound (VOC) emissions from water and water-based products is of great significance for indoor air quality because many household products (e.g., pesticides, hard-surface cleaners, and some aerosol products) are aqueous solutions. It is well established that predicting VOC emissions from these products requires knowledge of the Henry's law constant and overall mass transfer coefficient (also known as total transfer velocity):

$$R = S K_{OL} (C_L - C_G / H) \quad (1)$$

$$R = S K_{OG} (C_L H - C_G) \quad (2)$$

where:

R = emission rate (µg/h),
S = source area (m²),
K_{OL} = overall liquid-phase mass transfer coefficient (m/h),

Figure 1 EPA's new "green" research facilities

K_{OG} = overall gas-phase mass transfer coefficient (m/h),
C_L = pollutant concentration in liquid (µg/m³),
C_G = pollutant concentration in air (µg/m³), and
H = dimensionless Henry's constant $[(\mu g/m^3)_{air}/(\mu g/m^3)_{liquid}]$.

The two overall mass transfer coefficients, K_{OL} and K_{OG}, are defined by Eqs. 3 and 4, respectively:

$$\frac{1}{K_{OL}} = \frac{1}{k_L} + \frac{1}{k_g H} \quad (3)$$

$$\frac{1}{K_{OG}} = \frac{H}{k_L} + \frac{1}{k_g} \quad (4)$$

where:

k_L = liquid-phase mass transfer coefficient (m/h), and
k_g = gas-phase mass transfer coefficient (m/h).

K_{OL} and K_{OG} are so closely related that one can regard them as the measurement of the same physical property on different scales, a case similar to weighing an object in kilograms and pounds. The conversion factor between K_{OL} and K_{OG} is the Henry's constant (Eq. 5):

$$K_{OL} = H K_{OG} \quad (5)$$

(Continued on Page 3)

Methods for estimating the overall mass transfer coefficients are available for ambient sources, such as oceans, lakes, and water treatment facilities. However, these methods cannot be applied to the indoor environments without certain adjustments because the indoor and outdoor conditions are very different. For instance, indoor sources are much smaller and shallower, and the indoor air movements are not as strong as the outdoor. There are no methods for estimating the overall mass transfer coefficient for small pools, puddles, and wet films that are often found in the indoor environments. To fill this data gap, we conducted a series of small chamber tests to experimentally determine the overall mass transfer coefficients for six compounds with the Henry's law constants (air/water partition coefficients) ranging from 3.33×10^{-7} to 3.67×10^{-3} (atm m³/mol). The estimated overall liquid-phase mass transfer coefficients for still solutions varied from 1.8×10^{-6} to 5.7×10^{-3} m/h; the estimated liquid-phase mass transfer coefficients were 9.78×10^{-3} m/h for the reference compound (oxygen) and 5.00×10^{-3} to 6.04×10^{-3} m/h for the test compounds.

An empirical method is proposed to estimate the overall mass transfer coefficient for still water solutions in the indoor environments. It consists of three steps: (1) estimate the gas-phase mass transfer coefficient (k_g) from the dimensionless Sherwood number, (2) estimate the liquid-phase mass transfer coefficient (k_L) from Eq. 6, and (3) calculate the overall mass transfer coefficient from Eqs. 3 or 4.

$$k_L(X) = 2.99 \times \sqrt{D_L(X)} \qquad (6)$$

where:

k_L(X) = liquid-phase mass transfer coefficient for compound X (m/h),and
D_L(X) = diffusivity in water for compound X (m²/h).

Figure 2 compares the predicted values with those estimated from the chamber data.

Although not difficult, the calculations of the proposed method are somewhat tedious. We have developed a computer program to handle all the calculations, including estimations of molecular diffusivity in air and water.

As a practical matter, researchers often want to know under what conditions K_{OL} can be approximated by either k_L or k_g. There have been many discussions on this matter for the ambient environment. In general, it depends on whether the gas- or liquid-phase mass transfer resistance is dominant in the overall mass transfer resistance ($1/K_{OL}$ or $1/K_{OL}$). Using the results of this work, Figure 3 illustrates the contribution of the gas-phase mass transfer resistance $1/(H\,k_g)$ to $1/K_{OL}$ as a function of H and k_g. For still water under typical indoor environmental conditions, we suggest that K_{OL} be approximated by k_L when $H > 10^{-1}$ and by k_g when $H < 10^{-4}$, where H is dimensionless (i.e., air/water partition coefficient). For more information, contact Zhishi Guo, 919-541-0185, **guo.zhishi@epa.gov.**

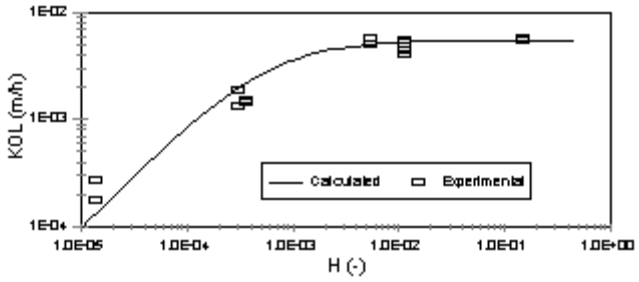

Figure 2. Comparison between experimental and calculated overall liquid-phase mass transfer coefficients. The solid line represents linearity.

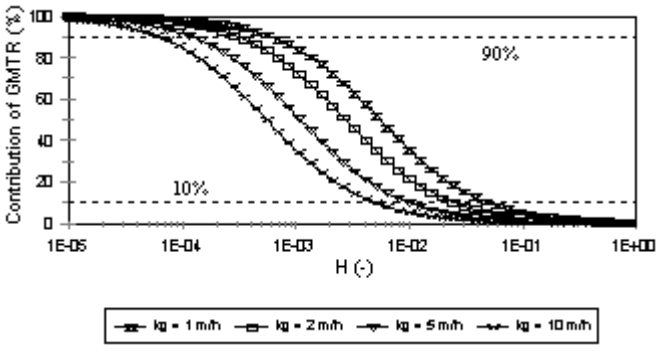

Figure 3. Contribution of the gas-phase mass transfer resistance (GMTR) to the overall mass transfer resistance ($1/K_{OL}$). The curves from left to right are for k_g = 10, 5, 2, and 1 m/h, respectively.

BIOLAB BEGINS OPERATION

The BioLab (BL) is a component of the Indoor Environment Management Branch of APPCD/NRMRL. The BL facility is a new state-of-the art BSL 2 microbiology research laboratory that performs research in the evaluation of biocontaminants such as mold, bacterial spores, toxins (mycotoxins, endotoxins), and allergens that have been recognized as the most common cause of building related illnesses. The BL facility is equipped with an ABI Genetic Sequencer for the analysis of DNA and RNA sequences; a BioRad *i*Cycler for amplifying DNA and RNA fragments using RT-PCR; the BIOLOG system for identification of mold and bacteria, Qcount an automated colony counter, as well as other supportive equipment in a microbiological laboratory.

In April 2003, the first draft of the BL Facility Manual was placed at the Network Neighborhood\Saturn\Public\APPCD\Facility Manuals.

Bioaerosol Sampling and Mold Analysis (In-House)

As the BL begins operations the initial focus will be on bioaerosol sampling of ambient and mold contaminated environments. Work will focus on optimizing sampling techniques, capture of airborne mold particles, and subsequent growth and enumeration technologies. Bioaerosol sampling will be conducted in diverse environments using an Andersen Cascade Impactor, Zefon Air-O-Cell filter cassettes, and Millipore aerosol analysis filters. Mold spores will be eluted from the capture membranes and enumerated by growth culture and Quantitative Polymerase Chain Reaction. Sequencing various genes on the ABI 3100 Genetic Analyzer in concert with BIOLOG analysis will complete identification of mold species by generating a molecular and physiological "fingerprint" for each organism. Currently, universal primers have been developed that will amplify portions of the 18S and 28S ribosomal subunits of various mold contaminants such *Aspergillus*, *Penicillium*, *Cladosporium*, and *Stachybotrys* spp. Amplification of this fragment will allow the region to be sequenced and individual base positions to be determined. It is the differences in the individual base positions that will be used to identify different species and different strains of the same species.

Microbial Survivability Test for Medical Waste Incinerator Materials:

The thermal destruction project, funded by the Department of Homeland Security, is another on-going research project in the BioLab in collaboration with APTB. The objective of this project is to determine the microbial survivability of *Bacillus anthracis* surrogates in building materials during the normal operation of a medical waste incinerator.

The BL facility will be in charge of the sample preparation (both sterile and inoculated building materials) as well as the post-incineration and exhaust air analysis. Samples to be incinerated will consist of various building materials inoculated with *Bacillus* surrogate spores. Post incineration materials will be analyzed for microbial survivability. The in-house analytical resources that will be used for pre/post incineration analyses are the BIOLOG microbial identification system and the QCount.

The main goal of this project is to determine the most efficient incineration method to destroy *Bacillus anthracis* spores.

For more information, contact Marc Menetrez, (919) 541-7981, menetrez.marc@epa.gov; Timothy Dean, (919)541-2304, dean.timothy@epa.gov; Doris Betancourt, (919)541-9446, betancourt.doris@epa.gov

Inside IAQ is distributed twice a year and highlights indoor air quality (IAQ) research conducted by EPA's National Risk Management Laboratory's (NRMRL) Indoor Environment Management Branch (IEMB).
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EMISSIONS FROM POPPING AND OPENING MICROWAVE POPCORN

In 2000, eight workers at a microwave popcorn production plant in Missouri were diagnosed with the rare disease bronchiolitis obliterans (Kreiss et al., 2002). Patients were as young as 26 years old (Parmet and Von Essen, 2002). As a result of this disease, at least four of these workers are on lung transplant lists (Kullman et al., 2002). Since the initial discovery, workers in at least six other microwave popcorn plants have been documented to have bronchiolitis obliterans (Kreiss et al., 2002).

The Missouri plant employees have 3.3 times the national rate of obstructive disease for smokers and 10.8 times the national rate for non-smokers (Kreiss et al., 2002). Workers in microwave production areas, including quality control personnel who pop corn and open bags, had higher incidence of respiratory and dermal symptoms (Kreiss et al., 2002). Discussions with National Institute for Occupational Safety and Health (NIOSH) scientists from Morgantown, WV confirm that workers in quality control areas have shown an increased risk of lung disease (Kullman, 2002; Kreiss, 2002). This may be due to the peak exposures received when popping and opening a bag of flavored popcorn.

The microwave popcorn production plant receives raw corn; mixes the corn with salt, oil, and flavorings; and packages it for microwave use (Parmet and Von Essen, 2002). The flavorings emit compounds such as diacetyl, other ketones, acetoin, and 2-nonanone (Kullman et al., 2002). While diacetyl was measured as marker for flavoring vapors, more than 100 volatile compounds were identified (Kreiss, 2002). Diacetyl is not listed as a workplace chemical hazard in NIOSH Pocket Guide to Chemical Hazards (Parmet and Von Essen, 2002), and no OSHA permissible exposure limit (PEL) or NIOSH recommended exposure limits exist for diacetyl. Particulate matter levels were below exposure limits for particulates not otherwise regulated (Simoes et al., 2002a; Simoes et al., 2002b).

The U.S. Food and Drug Administration regulates flavorings based on ingestion safety, not on inhalation safety (Simoes et al, 2002a; Simoes et al, 2002b); thus, inhalation toxicology studies on popcorn flavorings had not been performed. Recent animal studies by NIOSH scientists found that butter flavoring vapors that produce diacetyl levels of 352 ppm severely damaged the respiratory epithelium of rats (Hubbs et al., 2002). It is feasible that recurrent exposure in the home environment may pose similar risks, especially in children and adults with compromised respiratory health.

Comprehensive sampling has not been performed to determine contaminants released when flavorings are heated to microwave temperatures. Thus, the primary goal of this work is to identify and quantify contaminants emitted while popping and opening a bag of microwave popcorn. Discussions with NIOSH scientists indicate that microwave popcorn flavorings, when heated, may produce a more complex spectra of compounds resulting in a higher exposure risk (Kullman, 2002; Kreiss, 2002). As no data is currently available to support this theory, the secondary goal of this work is to complete a mass balance on compounds found in microwave popcorn by comparing pre-pop extraction data with popping emissions and post-pop extraction data.

This project will proceed in two phases. Phase I will be exploratory in nature. In this phase we will identify the compounds emitted while popping and opening popcorn and will make estimates of compound concentrations. Compounds of particular interest include diacetyl, acetoin, butyric acid, and 2-nonanone. In addition to identifying and quantifying compounds emitted into the air, procedural and analytical details (e.g., surrogate choices, sampling volumes, extraction volumes, and flow rates) will be refined. Phase I will be performed in a small box-like chamber of sufficient size to hold a microwave oven. This chamber is being built specifically to accommodate this study.

Phase II will quantitatively evaluate the emitted compounds identified in Phase I for both corn popping and bag opening. In addition, a mass balance will be performed with Phase II data to determine whether the sum of contaminants released during popping and present after-popping are different in type or amount than those present in pre-popped microwave popcorn. Phase II will also evaluate whether the microwaveable

(Continued on Page 6)

bag used for popcorn emits VOCs during popping/heating. Phase II will also be performed in the small box-like chamber built for this study.

Research is expected to be completed by December of 2003.

For more information, contact Jacky Rosati, (919) 541-9429 (rosati.jacky@epa.gov)

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EVALUATION OF COATINGS TO MINIMIZE POTENTIAL DERMAL EXPOSURE TO ARSENIC ON PRESSURE TREATED WOOD (CCA)

In collaboration with EPA's Office of Pesticide Policy and the Consumer Product Safety Commission, IEMB is evaluating the ability of selected coatings to reduce the amount of arsenic that can be wiped from the surfaces of CCA (Chromated copper arsenate) treated wood. CCA is a chemical wood preservative injected under high pressures to protect wood from decay and insect damage. The manufacturers of CCA treated wood have asked EPA to remove registration of this product for residential use, including playground equipment, decks, and landscape timbers, and they intend total conversion to alternative treatments by December 31, 2003. However, there remains extensive potential for dermal contact with arsenic residues on treated surfaces, and the potential is greatest for the most susceptible subpopulation, infants and small children, due to their close contact with surfaces and hand to mouth activities. A recent field survey of CCA treated surfaces indicates that widely used deck sealants are often not effective at preventing arsenic contamination of surfaces beyond six months. The purpose of this project is to evaluate performance for several deck sealants and stains. The project will also evaluate a limited number of encapsulants and film forming finishes. The information generated by this project will assist the public in determining how to reduce exposure to arsenic and provide the coatings industry with a methodology that they can use to evaluate the ability of their products to prevent dermal exposure from CCA treated wood.

Selected products will be applied to "mini-decks" constructed from CCA treated deck boards recovered from two decks, an older deck that received considerable use over several years serving as an outdoor extension of a cafeteria, and a much newer deck (approximately 2 years old) that was located outside but

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never placed into active service. Once the mini-decks have been assembled, they will be prepared for coating by a standard protocol. Only one coating will be applied to each mini-deck to minimize the potential for cross contamination. The mini-decks will receive full-sun exposure in a natural, out-of-doors setting. Periodically, as the mini-decks weather and age, we will determine the amount of arsenic, chromium, and copper that can be wiped from the surfaces of the deck boards. Sampling may continue for up to two years and will provide insight into initial and longer-term ability of various coatings to reduce arsenic that may be wiped from the surface of the CCA treated deck boards. (Mark A. Mason 919 541-4835, mason.mark@epa.gov).

SUMMARIES OF RECENT PUBLICATIONS

Microbial Volatile Organic Compound Emission Rates and Exposure Model - This paper presents the results from a study that examined microbial volatile organic compound (MVOC) emissions from six fungi and one bacterial species (*Streptomyces* spp.) commonly found in indoor environments. Data are presented on peak emission rates from inoculated agar plates loaded with surface growth, ranging from 33.5 µg per m^2 per 24 hours *(Cladosporium sphaerospermum)* to 515 µg per m^2 per 24 hours (*Rhodotorula glutinis*). Furthermore, changes in MVOC emission levels over the growth cycle of two of the microorganisms are examined. This report also includes a calculation of the impact of MVOC emissions on indoor air quality in a typical house and an application of an exposure model used in a typical school environment. **Source: *Indoor Built Environment,* Vol. 11, pp. 208-213, 2002. (EPA Contact: Marc Menetrez, 919-541-7981, menetrez.marc@epa.gov)**

Characterization and Reduction of Formaldehyde Emissions from a Low-VOC Latex Paint - The patterns of formaldehyde emission from a low volatile organic compound (VOC) latex paint applied to gypsum board were measured and analyzed by small environmental chamber tests. It was found that the formaldehyde emissions resulted in sharp increase of chamber air formaldehyde concentration to a peak followed by transition to a long-term slow decay. A first-order decay in-series model was developed to interpret the chamber data. The model characterized the formaldehyde emissions from the paint in three stages; an initial puff of instant release, a fast decay, and a final stage of slow decay controlled by a solid-phase diffusion process that can last for more than a month. The model was also used to estimate the peak concentration and the amount of formaldehyde emitted during each stage. The formaldehyde sources were investigated by comparing emission patterns and modeling outcomes of different paint formulations. The biocide used to preserve the paint was found to be a major source of the formaldehyde. Chamber test results demonstrated that replacing the preservative with a different biocide for the particular paint tested resulted in an approximately 55% reduction of formaldehyde emissions, but the reduction affected only the third-stage long-term emissions. **Source: *Indoor Air,* Vol. 12, No. 1, pp. 10-16, 2002. (EPA Contact: John Chang, 919-541-3747, chang.john@epa.gov)**

Review of Indoor Emission Source Models-Part 1. Overview - Indoor emission source models are mainly used as a component in indoor air quality (IAQ) and exposure modeling. They are also widely

used to interpret the experimental data obtained from environmental chambers and buildings. This paper compiles 46 indoor emission source models found in the literature. They represent the achievements that IAQ modelers have made in recent years in modeling indoor sources. While most models have a certain degree of usefulness, genuine predictive models are still few, and there is undoubtedly much room for improvement. This review consists of two sections. Part 1 - this paper - gives an overview of the 46 models, briefly discussing their validity, usefulness, limitations, and flaws (if any). Part 2 focuses on parameter estimation, a topic that is critically important to modelers but has not been systematically discussed. **Source: *Environmental Polution*, Vol. 120, No. 3, pp. 533-549, 2002. (EPA Contact: Zhishi Guo, 919-541-0185, guo.zhishi@epa.gov)**

Review of Indoor Emission Source Models: Part 2. Parameter Estimation - This review consists of two sections. Part 1 provides an overview of 46 indoor emission source models. Part 2 (this paper) focuses on parameter estimation, a topic that is critical to modelers but has never been systematically discussed. A perfectly valid model may not be a useful one if its parameters are difficult to estimate in the absence of experimental data. This is true for both statistical and mass transfer models. Thirty-seven methods are compiled and reviewed in this paper. Overall, developing methods for parameter estimation has fallen far behind developing the models. Such imbalance is the main reason that many models have been left on the shelf since they were published. **Source: *Environmental Polution*, Vol. 120, No. 3, pp. 551-564, 2002. (EPA Contact: Zhishi Guo, 919-541-0185, guo.zhishi@epa.gov)**

Testing Antimicrobial Efficacy on Porous Materials - The efficacy of antimicrobial treatments to eliminate or control biological growth in the indoor environment can easily be tested on nonporous surfaces. However, the testing of antimicrobial efficacy on porous surfaces, such as those found in the indoor environment [i.e., gypsum board, heating, ventilating, and air-conditioning (HVAC) duct-liner insulation, and wood products] can be more complicated and prone to incorrect conclusions regarding residual organisms and nonviable allergens. Research to control biological growth using three separate antimicrobial encapsulants on contaminated duct-liner insulation has been performed in both field and laboratory testing. The results indicate differences in antimicrobial efficacy for the period of testing. ***Source: Indoor Built Environment, Vol. 11, pp. 202-207, 2002. (EPA Contact: Marc Menetrez, 919-541-7981, menetrez.marc@epa.gov)***

Evaluating the Potential Efficacy of Three Antifungal Sealants of Duct Liner and Galvanized Steel as Used in HVAC Systems - Current recommendations for remediation of fiberglass duct materials contaminated with fungi specify complete removal, which can be extremely expensive, but in-place duct cleaning may not provide adequate protection from regrowth of fungal contamination. Therefore, a common practice in the duct-cleaning industry is the postcleaning use of antifungal surface coatings with the implication that they may contain or limit regrowth. However, even the proper use of these products has generally been discouraged because little research has been conducted on the effectiveness of most products as used in heating, ventilating, and air-conditioning (HVAC) systems. Three different coatings were evaluated on fiberglass duct liner (FGDL). Two of the three coatings were able to limit growth in the 3-month study; the third did not. One of the coatings that was able to limit growth was further evaluated in a comparison of FGDL or galvanized steel (GS) under conditions that mimicked their use in HVAC systems. The results showed that both moderately soiled and heavily soiled uncoated FGDL and GS duct material can support fungal growth, but that GS duct material was more readily cleaned. The use of an antifungal coating helped limit, but did not fully contain, regrowth on FGDL. ***No regrowth was detected on the coated GS. Source: J. Ind Microbiol Biotechnol, Vol. 29, No. 1, pp. 38-43, 2002. (EPA Contact: Marc Menetrez, 919-541-7981, menetrez.marc@epa.gov)***

An Analytical Method for the Measurement of Nonviable Bioaerosols - Exposures from indoor environments are a major issue for evaluating total long-term personal exposures to the fine fraction (<2.5 µm in aerodynamic diameter) of particulate matter (PM). It is widely accepted in the indoor air

quality (IAQ) research community that biocontamination is one of the important indoor air pollutants. Major indoor air biocontaminants include mold, bacteria, dust mites, and other antigens. Once the biocontaminants or their metabolites become airborne, IAQ could be significantly deteriorated. The airborne biocontaminants or their metabolites can induce irritational, allergic, infectious, and chemical responses in exposed individuals. Biocontaminants such as some mold spores or pollen grains, because of their size and mass, settle rapidly within the indoor environment. Over time they may become non-viable and fragmented by the process of desiccation. Desiccated non-viable fragments of organisms are common and can be toxic or allergenic, depending upon the specific organism or organism component. Once these smaller and lighter fragments of biological PM become suspended in air, they will have a greater tendency to stay suspended. Although some bioaerosols have been identified, few have been quantitatively studied for their prevalence within the total indoor PM with time, or their affinity to penetrate indoors.

This paper describes a preliminary research effort to develop a methodology for the measurement of non-viable biologically based PM, analyzing for mold, ragweed antigens, and endotoxins. The research objectives include 1) develop a set of analytical methods and compare impactor media and sample size, and 2) quantify the relationship between outdoor and indoor levels of bioaerosols. Indoor and outdoor air samples were passed through an Andersen Non-Viable cascade impactor in which particles from 0.2 to 9.0 µm were collected and analyzed. The presence of mold, ragweed, and endotoxin was found in all 8 size ranges. The presence of respirable particles of mold and pollen found in the fine particle size range from 0.2 to 5.25 µm is evidence of fragmentation of larger source particles that are known allergens. ***Source: J. Air & Waste Management Association, Vol. 51, pp. 1436-1442, 2001. (EPA Contact: Marc Menetrez,919-541-7981, menetrez.marc@epa.gov)***

Lead in Candle Emissions – The purpose of this work was to investigate the local prevalence of lead-wick candles, to measure their air lead (PbA) emission rates, to investigate the partition of lead between air and ashes, to assess a lead mass balance, and to model concentration, exposure, and deposition for realistic scenarios. We also investigated a definitive association between respirable particulate and lead. This question is important because of the potential risk to human health represented by the some $1 to $2 billion worth of candles sold in the United States annually. Assuming $5/candle, this sales figure represents an average of about 300 million candles. If even 1% have lead in the core of the wick, at least 3 million candles are potential lead emitters. Depending upon the amount of candle burning activity, the number burning simultaneously, and indoor room conditions, lead concentrations in excess of both environmental and occupational standards could occur. While the primary danger is from inhalation, the deposition of lead-bearing fine particulate in household dust provides a secondary exposure route for babies and toddlers due to their ubiquitous hand-to-mouth behavior. To define the problem, 100 sets of candles (two or more identical candles) were purchased locally. The criterion for purchase was that the candles must appear to contain a metal-cored wick or be covered by a metallic pigment. Of the candles purchased, 8% contained lead wicks. The wicks were 39 to 74% lead (remainder, fabric or paper), and the lead cores (approximately 100% lead) had linear densities of 13 to 27 mg/cm. Candles were burned to completion in a closed chamber to capture the air emissions, and the candle residue was extracted to assess the lead mass balance. It was found that individual candles emitted lead to the air at average rates that ranged from 100 to 1700 µg/hr. Assuming realistic indoor conditions, these emission rates were modeled to project room air concentration, child exposure by inhalation, and indoor deposition. Results showed that burning single candles can easily raise the source room concentration above the ambient air lead concentration limit of 1.5 $\mu g/m^3$ set by EPA . Burning multiple candles can elevate it

above OSHA permissible exposure limits of 50 µg/m^3. Although blood lead levels have dropped precipitously in the United States since lead was phased out of gasoline in 1986, nearly 900,000 children still had levels above 10 µg/dL during NHANES III. Considering candle sales in the United States and that children may spend as much as 88% of their time indoors, it is reasonable to suspect that some blood lead elevation in children arises from indoor microenvironments where lead-wick candles are burned. In a response to the problem, the U. S. Consumer Product Safety Commission issued a rule in April, 2003, banning candles with lead wicks. **Source: *The Science of the Total Environment*, Vol. 296, Issues 1 - 3, 159-174, 2002. (EPA Contact: Shirley Wasson, 919-541-1439, wasson.shirley@epa.gov)**

Analysis of Lead in Candle Particulate Emissions by XRF Using UniQuant® 4 - As part of an extensive program to study the small combustion sources of indoor fine particulate matter (PM), candles with lead-core wicks were burned in a 46-L glass flow-through chamber. The particulate emissions with aerodynamic diameters <10 µm (PM_{10}) were captured on quartz filters and analyzed under vacuum in a Philips PW 2404 wavelength-dispersive X-Ray Fluorescence (WDXRF) Spectrometer. UniQuant® 4 software was used to calculate the filter lead concentrations. Particulate filter loading masses ranged from 0.18 to 52.1 mg. The lead concentrations ranged from 0.2 to 80% by weight, with carbon comprising the remainder of the matrix. The method was validated by analyzing 87 filters, first by XRF and then by EPA Method 12 atomic absorption spectroscopy (AAS). For 84 filters, the average particle mass recovery after XRF analysis was 99±6%. For 84 filters analyzed for lead by both methods, the average recovery of lead by XRF compared to the AAS analysis was 108±9%. Modeling of candle emissions using typical room ventilation scenarios showed that even low-emitting candles can produce a lead concentration above the EPA National Ambient Air Quality Standard (NAAQS) of 1.5 µg/m^3 (quarterly average). Burning more than one heavily emitting candle in a poorly ventilated space can produce concentrations exceeding the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) concentration of 50 µg/m^3 (8-hour time-weighted average). **Source: *Advances in X-Ray Analysis*, Vol. 45, 539-543, 2002. (EPA Contact: Shirley Wasson, 919-541-1439, wasson.shirley@epa.gov)**

NEWS FROM NERL

STUDYING THE INFLUENCE OF AMBIENT PARTICULATE MATTER ON INDOOR CONCENTRATIONS: FIELD STUDIES OF SENSITIVE POPULATIONS

Although scientists know that particulate matter (PM) affects human health, we need to know more about the sources of PM, how people come in contact with it, and how levels of PM outdoors influence PM concentrations indoors.

EPA's National Exposure Research Laboratory (NERL) recently completed three longitudinal PM exposure field studies. These studies were conducted in Baltimore, Maryland (1998), Fresno, California (1999), and Research Triangle Park (RTP), North Carolina (2000-2001) and were designed to evaluate factors that influence the contribution of ambient PM to residential indoor PM concentrations. The studies addressed selected non-smoking sub-populations that might be sensitive to potential exposures to ambient PM: the elderly, hypertensive, and cardiac impaired. Different geographical settings, seasons, and housing types were included. The Baltimore and Fresno measurements were conducted in retirement facilities; the RTP study was conducted in 38 single-family homes.

The studies were of sufficient duration (28 days) and size (20-60 participants) to investigate both longitudinal and cross-sectional correlations between personal, residential indoor, residential outdoor, and ambient PM measurements. Residential measurements of PM2.5, PM10, and PM10-2.5 were routinely collected. Additional pollutants were also collected in some of the studies. In addition, detailed questionnaires were used to gather information on daily household activities and other factors that might influence particle infiltration.

Results from these three field studies showed mean indoor/outdoor PM2.5 mass concentration ratios ranging from 0.49 to 1.12 µg/m3. The single-family home data from the RTP study provided the opportunity for a more detailed examination of select particle infiltration issues. These results showed a wide range in the magnitude and variability of individual residential indoor PM2.5 24-hour average PM mass concentrations (4 to 119) over the course of one year. The mean least squares estimate of individual residences PM2.5 ambient particle infiltration rates (Finf) was 0.42 ± 0.38, indicating the high degree of infiltration variability in the RTP homes.

For more information, contact Ron Williams, ORD/NERL, 919-541-2957 (williams.ron@epa.gov).

GLOSSARY

ACH - Air Change per Hour
AHU - Air Handling Unit
CFU - Colony Forming Unit
DMTC - Dynamic Microbial Test Chamber
FDL - Fiberglass Duct Liner
FGD - Fiberglass Ductboard
GC/MS - Gas Chromatography/Mass Spectrography
HEPA - High Efficiency Particulate Air
IAQ - Indoor Air Quality
IEMB - Indoor Environment Management Branch
MEKO - Methyl Ethyl Ketoxime
NERL - National Exposure Researchg Laboratory
NRMRL - National Risk Management Research Laboratory
P2 - Pollution Prevention
RH - Relative Humidity
STKi - Simulation Tool Kit for IAQ and exposure
TVOC - Total Volatile Organic Compound
VOC - Volatile Organic Compound

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